# Quantum Computer Project
## Accelerating Advanced Computing

NASA's quantum computing project is an experiment to assess the potential of quantum computers to perform calculations that are difficult or impossible using conventional supercomputers in a realistic timeframe. The project is a collaboration among teams at NASA, Google, and the Universities Space Research Association (USRA).

The NASA team aims to demonstrate that quantum computing and quantum algorithms may someday dramatically improve the agency's ability to solve difficult optimization problems for aeronautics, Earth and space sciences, and space exploration missions.

Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer.

In summer 2013, engineers installed a D-Wave Two™ quantum computer in the new Quantum Artificial Intelligence Laboratory (QuAIL) located in the NASA Advanced Supercomputing (NAS) facility at NASA's
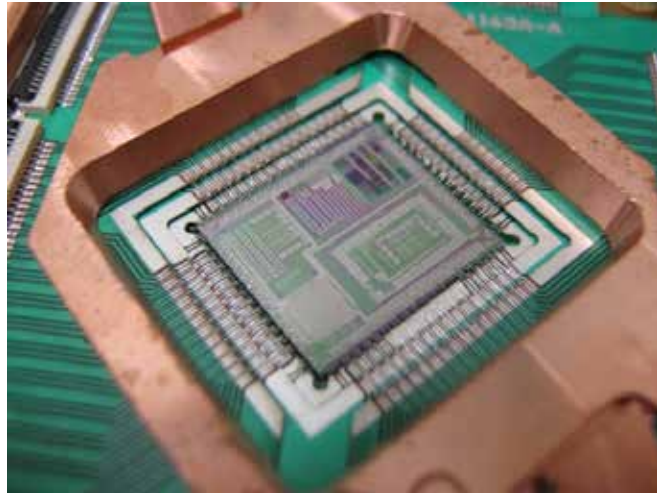


*The D-Wave superconducting 512-qubit Vesuvius processor chip.*

Ames Research Center, Moffett Field, Calif. The Vesuvius™ processor is housed inside a cryogenics system within a 10-square-meter box that blocks out the Earth's magnetic field. Currently, it is the most powerful system of its kind in the world, with 512 superconducting flux qubits.

The D-Wave Two system began operating in September, and NASA researchers have begun initial studies on quantum approaches to optimization problems in areas such as air traffic control, machine autonomy, verification and validation, and mission planning and scheduling. Through testing of problems in these disciplines, NASA's quantum computing team hopes to demonstrate that large-scale quantum computers will be able to solve certain problems much faster than any classical computer using the best currently known optimization algorithms.

One initial application is in the area of planning and scheduling. Automated planners developed at NASA Ames have been used extensively for missions such as the Mars Science Laboratory's Curiosity rover and for software that helps optimize operations of the International Space Station's solar arrays. So far, QuAIL researchers have developed benchmark sets of hard optimization problems that allow them to compare the effects of different quantum annealing approaches and existing state-of-the-art classical
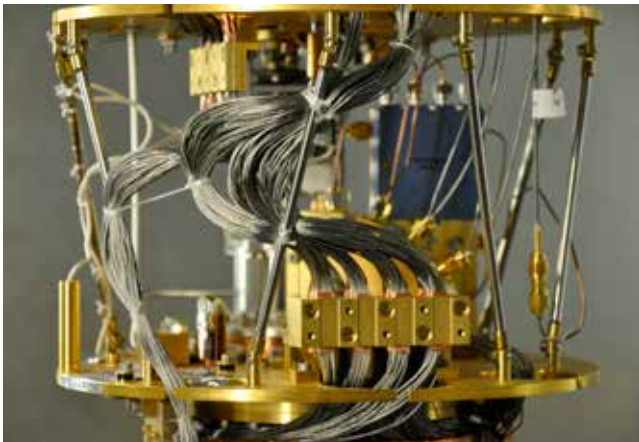


*Dilution refrigerator containing the D-Wave Vesuvius processor.*

**NASAfacts**

planners. They have also developed four representations of these planning problems, in a form suitable to be run on the quantum hardware.

Another early application is related to the NASA Kepler mission's search for habitable, Earth-sized planets. The complex computational task of validating and analyzing the light signals of transiting planets as they orbit their host stars is currently based on heuristic algorithms (designed to find approximate solutions when classical methods do not find exact solutions), implying that some planets could remain undiscovered due to this computational limitation. Using a quantum computer to perform Kepler's data-intensive search for transiting planets among the more than 150,000 stars in the spacecraft's field of view has the potential to provide a unique, complementary approach to the task of discovering potential new Earth-like exoplanets.

In addition, the broader academic community, through USRA, will utilize the D-Wave Two system and, in collaboration with researchers at both NASA and Google, conduct research on the benefits of quantum computing.

Through a five-year, non-reimbursable Space Act Agreement between NASA, Google, and USRA, the project team will conduct four main technology tasks: quantum computer acceptance tests; development of quantum AI algorithms and mapping them onto the system; development of problem decomposition and hardware embedding techniques; and creating quantum-classical hybrid algorithms.

The first results from NASA's experiments in applying early quantum annealers to problems related to practical applications have appeared in a series of 2014 technical reports and publications. These initial results are providing insight into architectural considerations and programming practices for future quantum annealing devices. Scientists expect that quantum computing will vastly improve a wide range of tasks that can lead to new discoveries and technologies, significantly changing the way we solve real-world problems.



*Flight controllers at the PHALCON (Power, Heating, Articulation, Lighting Control Officer) console at NASA's Mission Control Center at Johnson Space Center manage the electricity available to operate the International Space Station systems and experiments.*

**For more information about the quantum computer, visit:**

http://www.nas.nasa.gov/quantum

**For more information about NASA's partnership with Google and USRA, visit:**

https://plus.google.com/+QuantumAILab/

http://www.usra.edu/quantum/

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